10.1071/AM24001
Australian Mammalogy

Supplementary Material

What can echolocation recordings reveal about the species composition, habitat specificity and structure of mangrove bat communities in the Northern Territory?

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Appendices (electronic)

Appendix 1. Bioregional descriptions (see Fig. 1).

DAC (Darwin Coastal): Has a mesic monsoon climate (1700 mm rainfall annually) and, like the ARC and TWI, is characterised by gently undulating plains on lateritised Cretaceous sandstones and siltstones mantled by sandy and loamy red and yellow earths and siliceous sands supporting tall open eucalypt forest with a shrub and cane grass understorey. Extensive, diverse floodplains are associated with the lower reaches of the many large river systems, with riparian vegetation fringing the rivers and substantial areas of rainforest. Extensive mangrove forests occur in embayments and river mouths, and fringing the coast.

TWI (Tiwi-Cobourg): In the most mesic part of the study area (2000 mm rainfall annually), and comprises thinly sand- and earth-mantled plains on lateritised Cretaceous sandstone plateau supporting eucalypt tall open forest over hummock and tussock grasses with rainforest patches. Some escarpments and coastal cliffs are present, along with extensive coastal beach dune systems supporting scrub, strand woodlands of sheoak, coastal saline marshes and extensive mangrove forest.

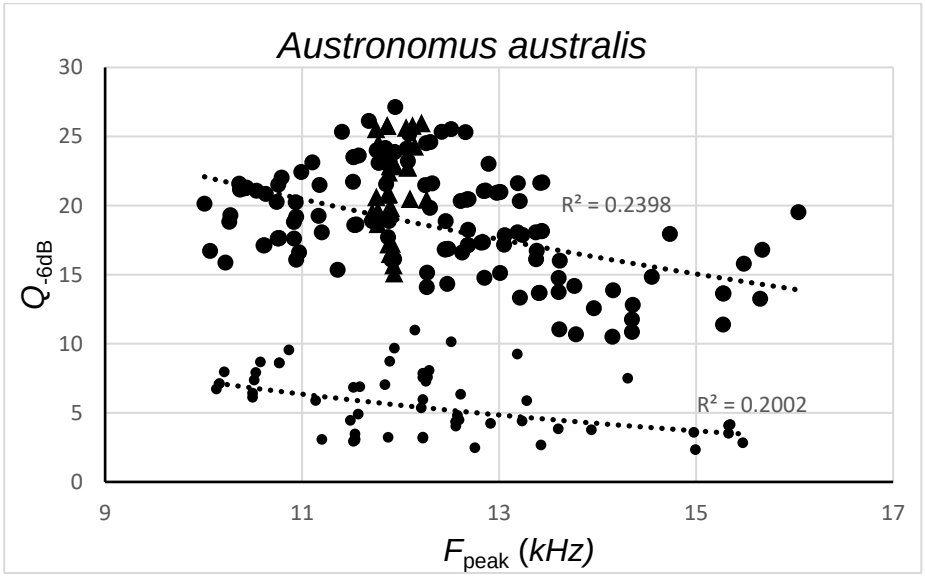
ARC (Arnhem Coast): With TWI, the most mesic bioregion in the study area (2000 mm rainfall annually). It includes sub-humid near-coastal as well as upland landscapes that are mainly expressed as coastal plains, gently undulating plains and low plateaux on lateritised Cretaceous sandstones and siltstones, as well as rugged, deeply incised, rocky, plateau surfaces dissected by gorges. The plains separate the uplands from the coast in places; they comprise extensive coastal dune systems, saline flats, wetlands and floodplains. Mangrove forests are common along the coast, particularly in sheltered embayments and estuaries. The wider landscapes of the uplands support grasslands, savannas, tree steppes, woodlands and open forests on: (1) red and yellow earths that mantle the undulating hill-country and broad valleys, and (2) rugged boulder country mainly associated with extensive quartz sandstone strata that are discontinuously mantled by skeletal soils. The uplands are drained by seasonally active, flood dominant river systems with many permanent pools fringed by tall trees that form riparian forests or woodlands.

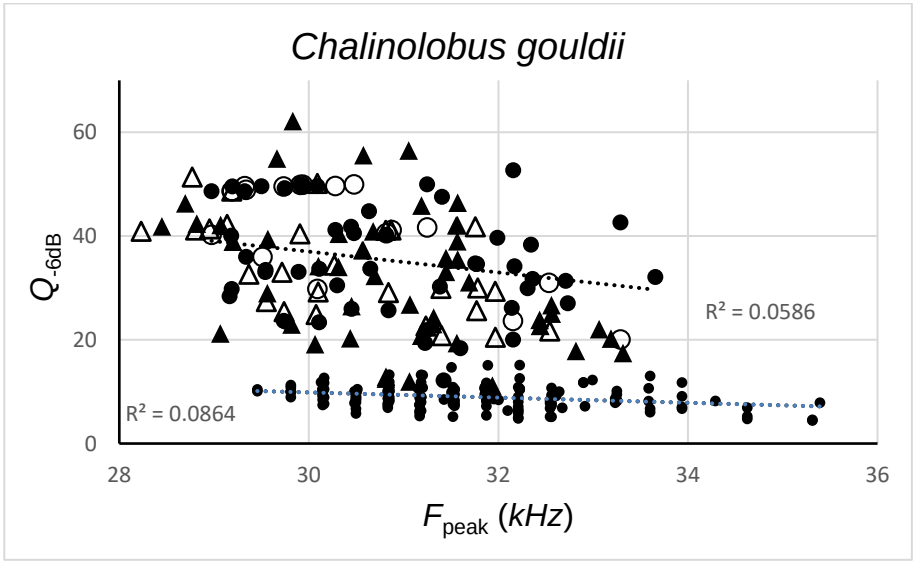
GUC (Gulf Coastal): Has a mesic monsoon climate, and receives 700 to 900 mm per annum. Its landscapes are dominated by gently undulating plains of red earths and shallow gravelly sand that support eucalypt woodlands over a tussock grass and spinifex understorey, with large meandering rivers and seasonal coastal swamps. Rugged areas on Proterozoic sandstone and Tertiary sediments occur in some places; coastal areas are not rocky, except on the Pellew Islands. The coastal plains support samphire shrublands and beach dunes. Mangrove forests are extensive along the coast, and fringe river estuaries for up to 10 km inland.

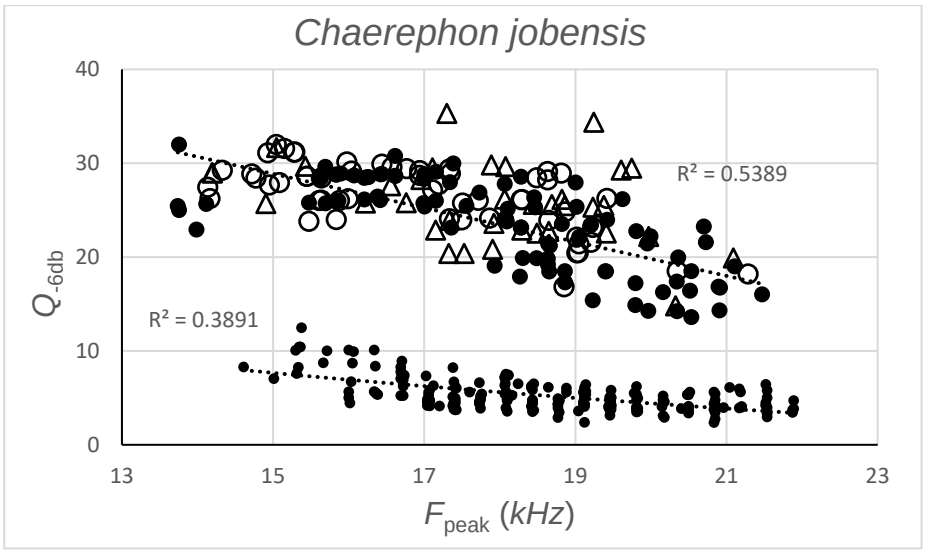
CEA (Central Arnhem): Has a mesic monsoon climate (1900 to 2000 mm rainfall annually). It comprises gently sloping upland terrain and low hills on Cretaceous sandstones, siltstones and lateritised

Tertiary material. These are discontinuously mantled by yellow earthy sands and shallow stony sands supporting open forests to woodlands of Darwin Woollybutt and Darwin Stringybark with a tussock and cane grass understorey. The uplands include some areas of rugged, deeply incised, rocky plateaux dissected by gorges, and are drained by seasonally active, flood dominant river systems with many permanent pools fringed by tall trees that form riparian forests or woodlands. Coastal areas comprise coastal dune systems, saline flats, wetlands and floodplains. Mangrove forests are common along the coast, particularly in sheltered embayments and estuaries.

Appendix 2. Species F_{peak} (= F_{peakC}, kHz) versus Q_{-6dB} plots of search-mode Anabat2 (zero-crossed) and full spectrum (FS) pulses emitted by Northern Territory, Kimberley and Pilbara bats (see final column in Table 6) in free flight at night. The small black dots are from our Anabat2 reference library and the small hollow triangles in the *Saccolaimus saccolaimus* plot are DFA-classified Anabat2 pulses (see McKenzie *et al*. 2018). The large solid black circles (Western Australian) and triangles (Northern Territory) are pulses from full spectrum reference recordings; the large hollow symbols are pulses from the full spectrum recordings that have been identified using reference library data. Individual pulses are displayed here, rather than the sequence averages plotted in Figs 2 and 3. Summary statistics for species F_{peak} and Q_{FS} are provided in Appendix 3.

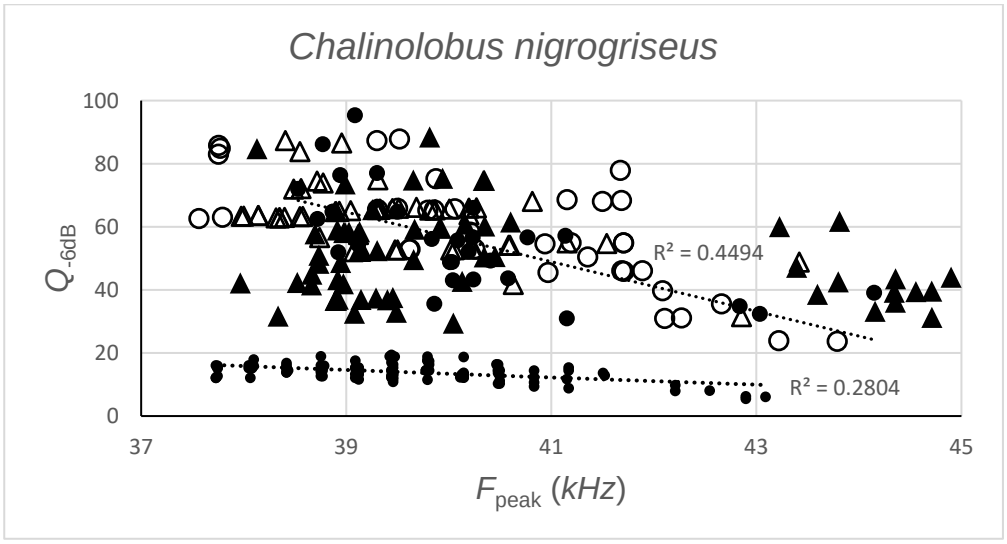






59

60



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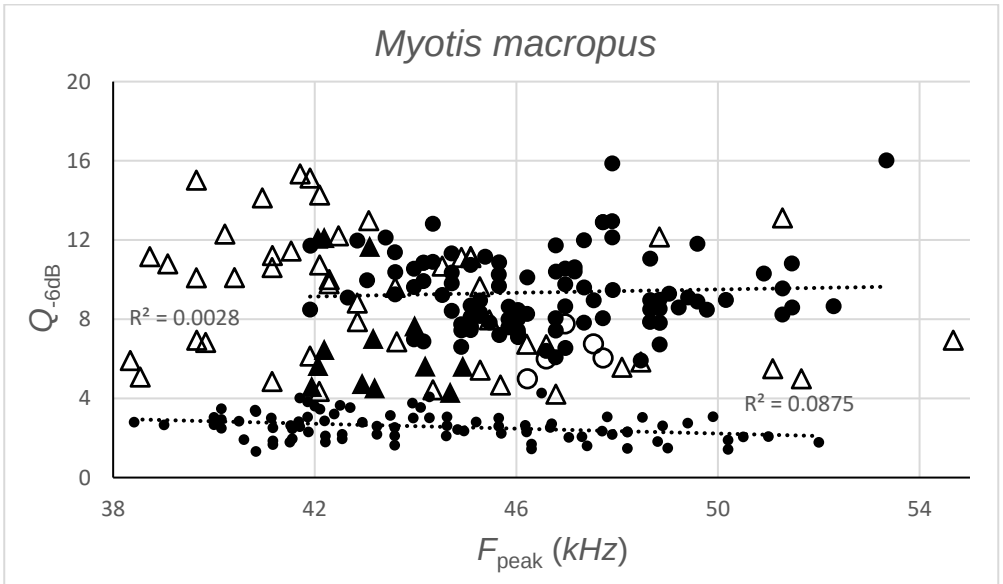

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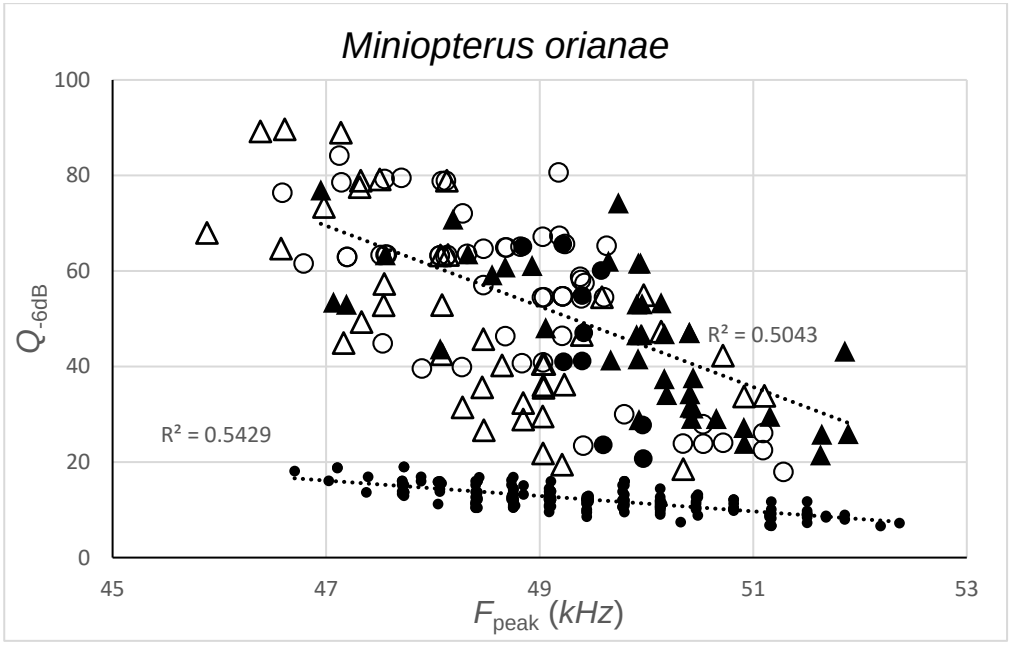
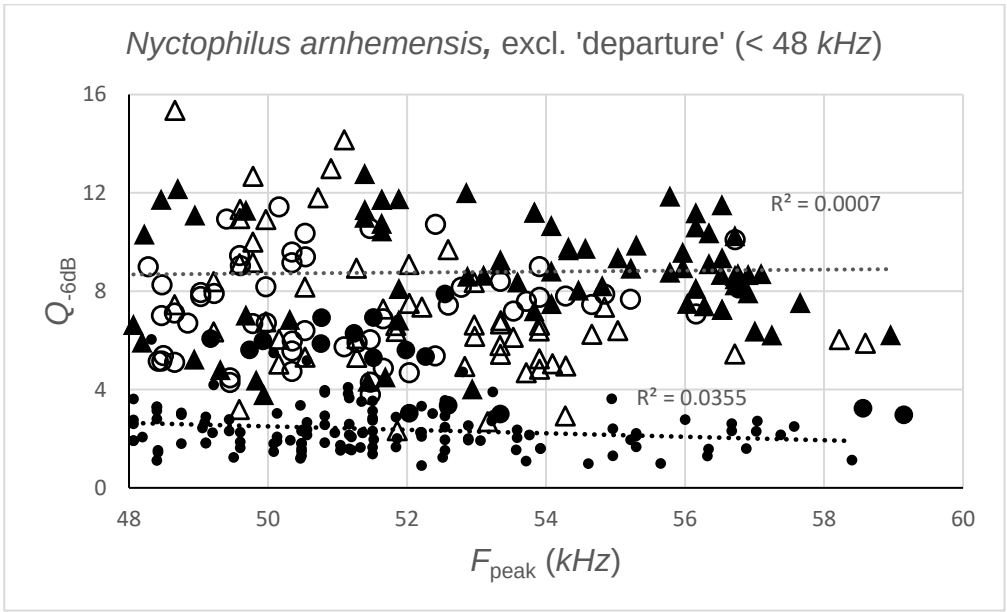
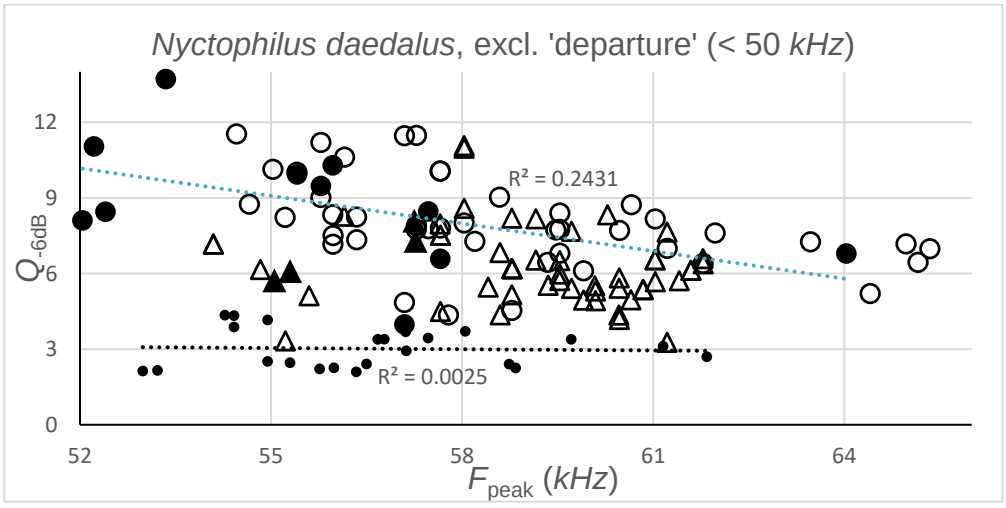
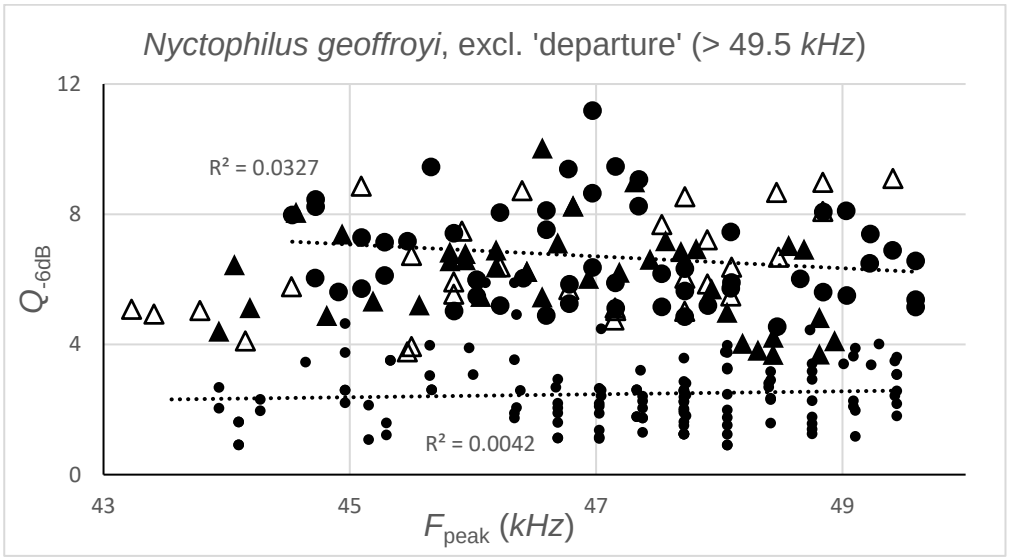
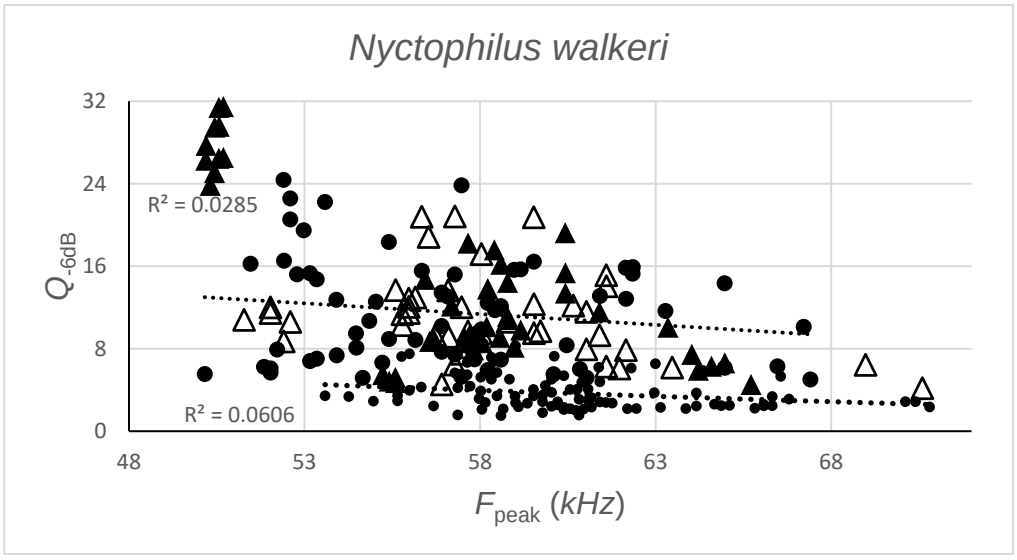
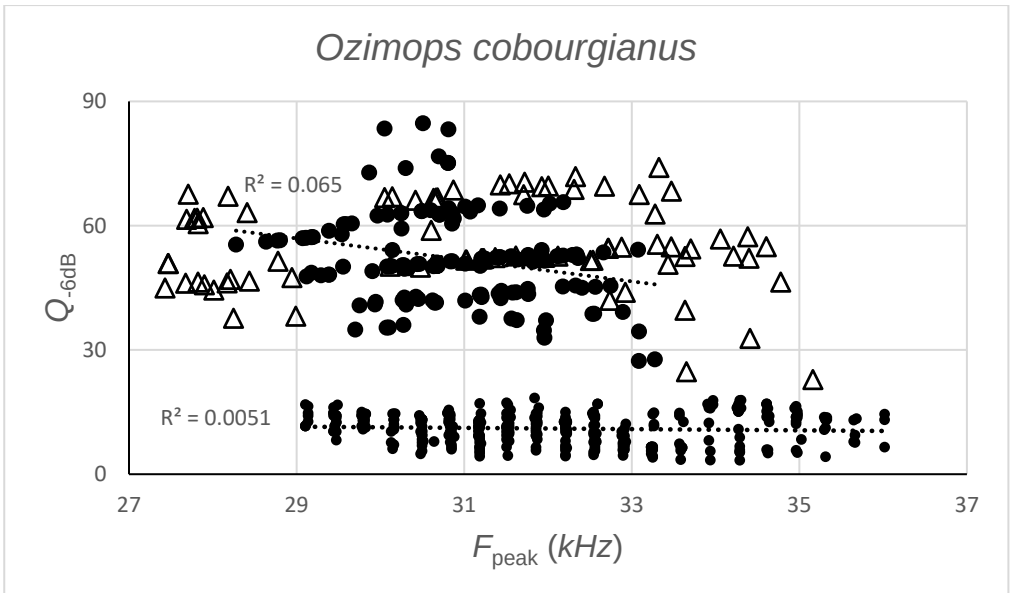

Miniopterus orianae
Q-6dB
F peak (kHz)
R² = 0.5043
R² = 0.5429
100
80
60
40
20
0
45
47
49
51
53

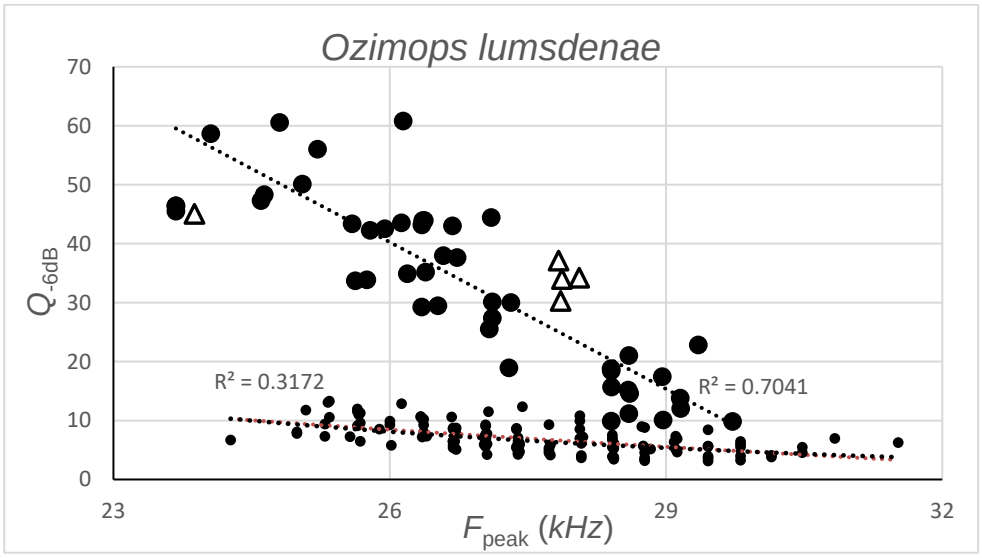

Nyctophilus arnhemensis, excl. 'departure' (< 48 kHz)
Q-6dB
F peak (kHz)
R² = 0.0007
R² = 0.0355
16
12
8
4
0
48
50
52
54
56
58
60

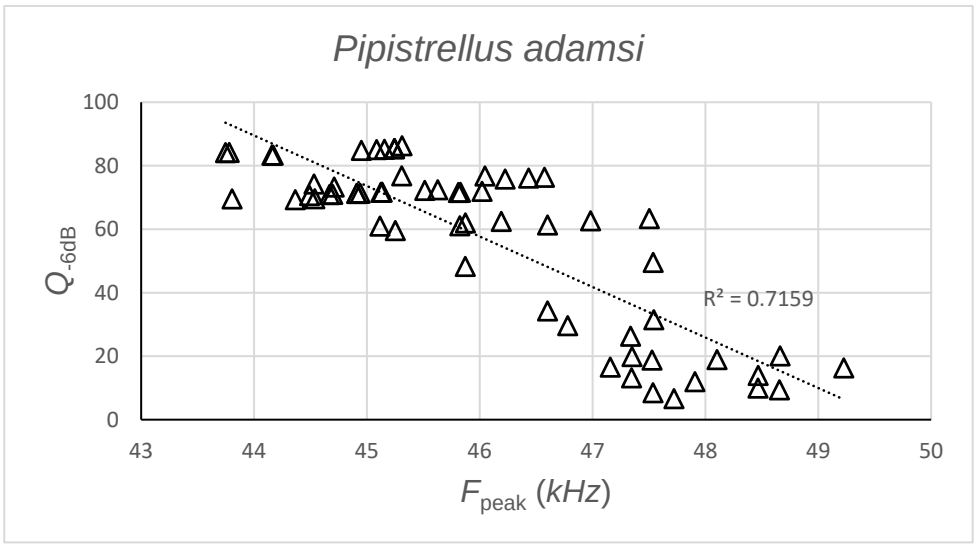

Nyctophilus daedalus, excl. 'departure' (< 50 kHz)
Q-6dB
F peak (kHz)
R² = 0.2431
R² = 0.0025
12
9
6
3
0
52
55
58
61
64

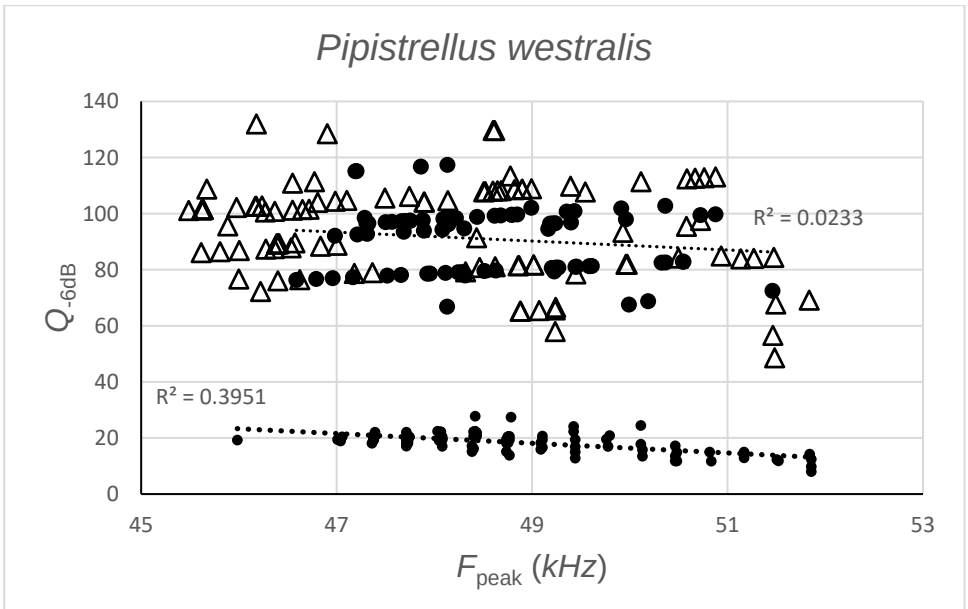

Nyctophilus geoffroyi, excl. 'departure' (> 49.5 kHz)
12
8
4
0
Q-6dB
R² = 0.0327
R² = 0.0042
43
45
47
49
Fpeak (kHz)

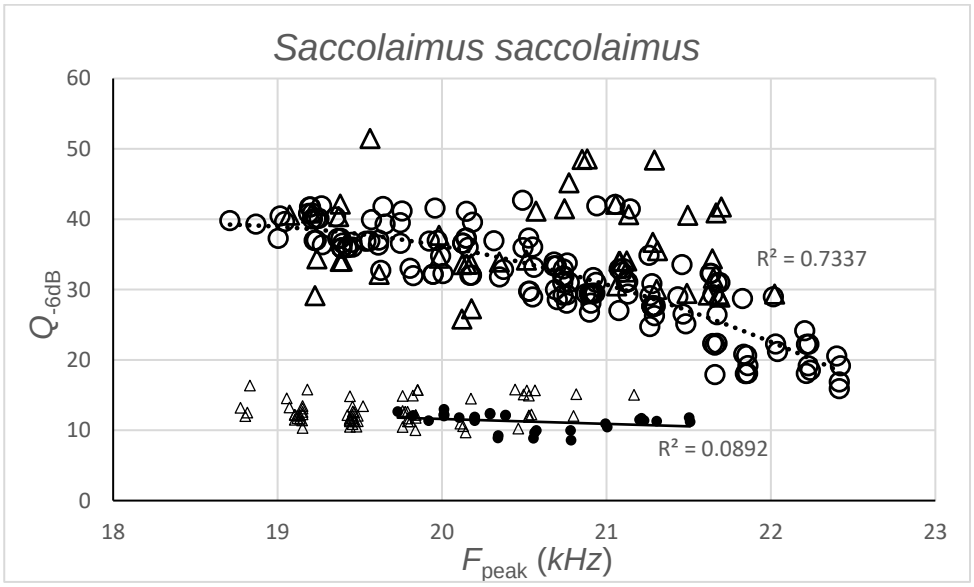

Nyctophilus walkeri
32
24
16
8
0
Q-6dB
R² = 0.0285
R² = 0.0606
48
53
58
63
68
Fpeak (kHz)

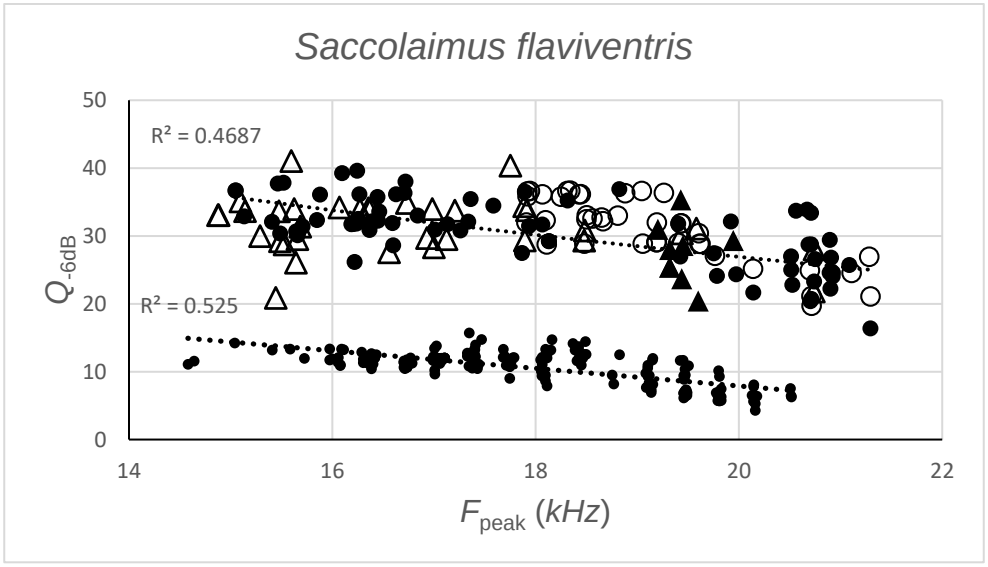

Ozimops cobourgianus
90
60
30
0
Q-6dB
R² = 0.065
R² = 0.0051
27
29
31
33
35
37
Fpeak (kHz)

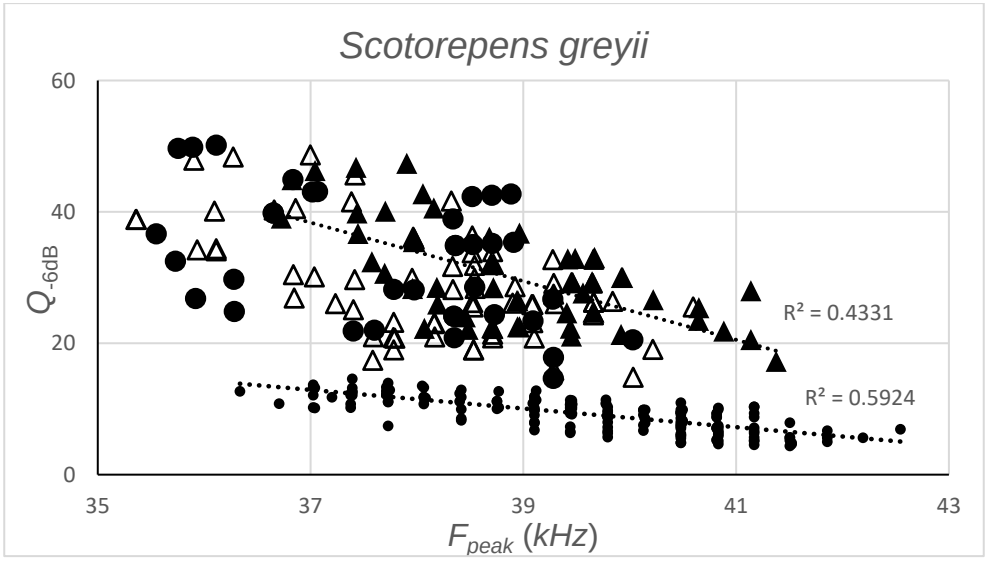

Ozimops lumsdenae
70
60
50
40
30
20
10
0
Q-6dB
R² = 0.3172
R² = 0.7041
23
26
29
32
F peak (kHz)

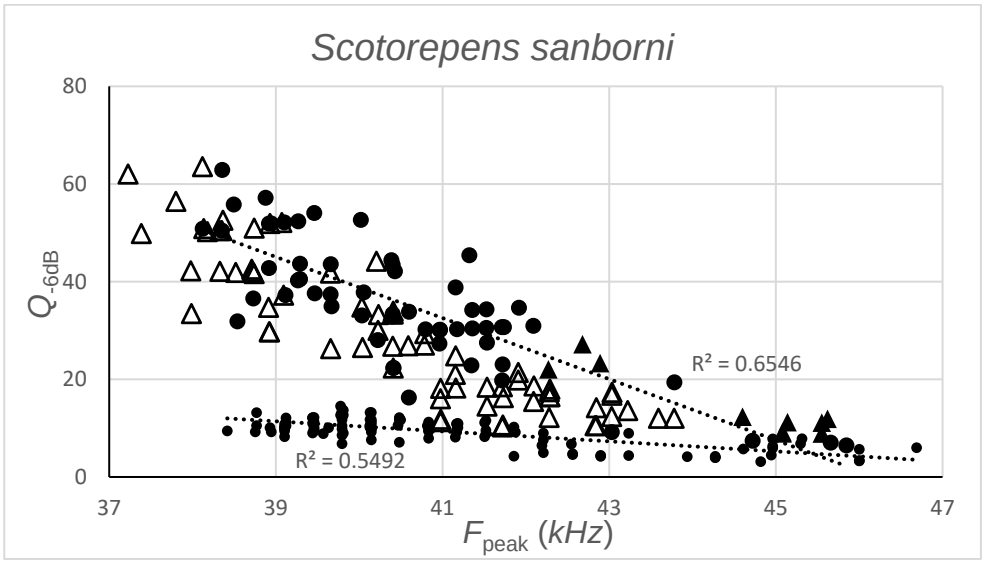

Pipistrellus adamsi
100
80
60
40
20
0
Q-6dB
R² = 0.7159
43
44
45
46
47
48
49
50
F peak (kHz)

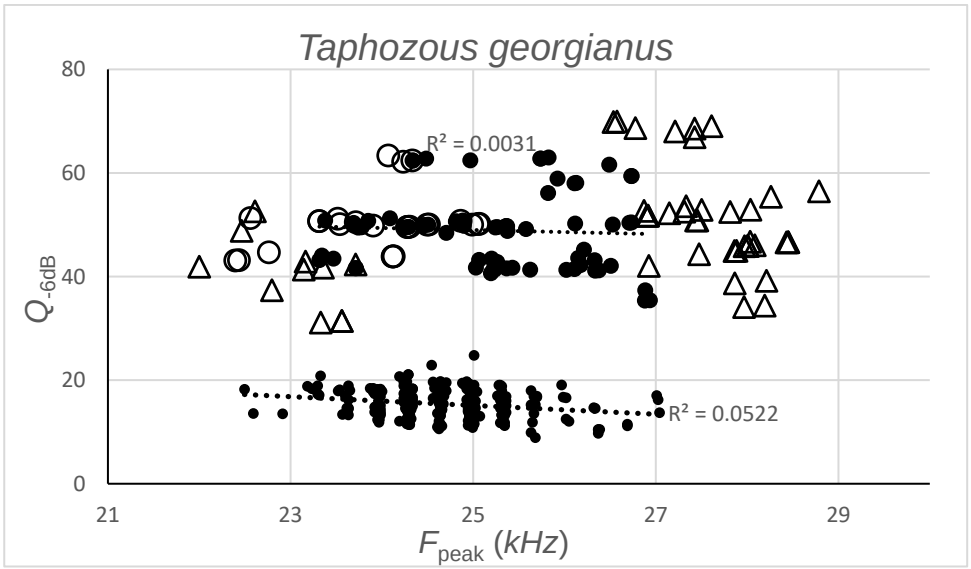

Pipistrellus westralis
140
120
100
80
60
40
20
0
Q-6dB
R² = 0.0233
R² = 0.3951
45
47
49
51
53
F peak (kHz)

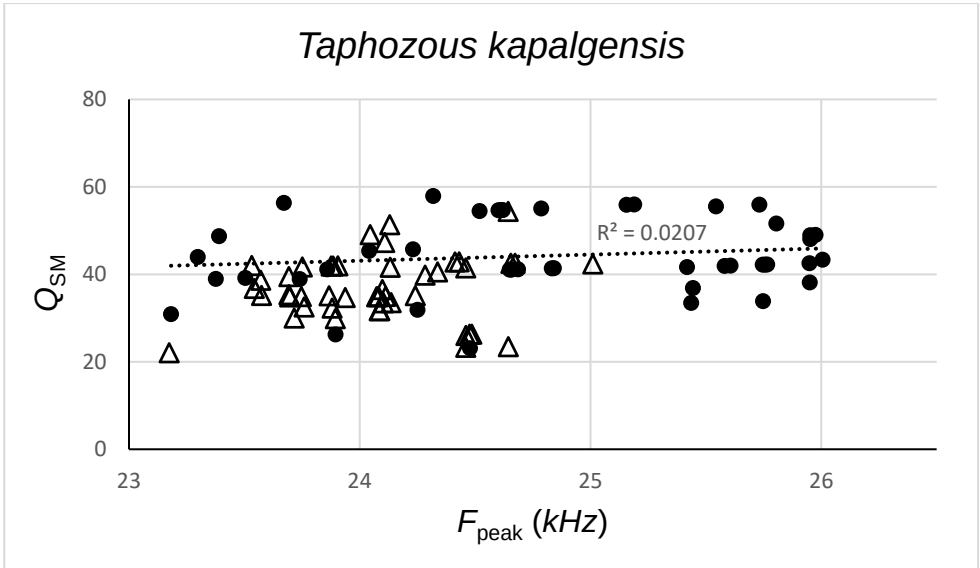

Saccolaimus saccolaimus
60
50
40
30
20
10
0
18
19
20
21
22
23
Q-6dB
R² = 0.7337
R² = 0.0892
Fpeak (kHz)

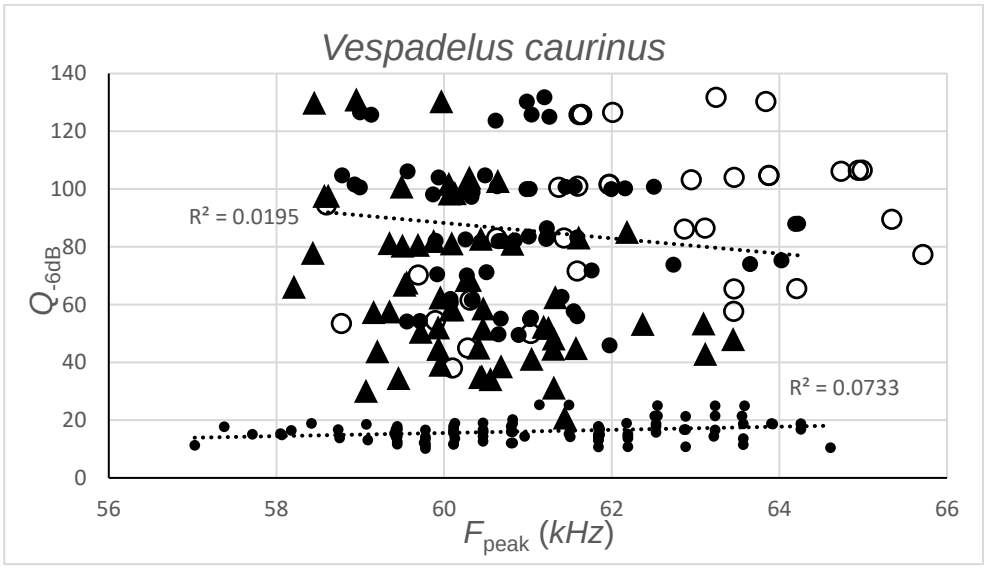

Saccolaimus flaviventris
50
40
30
20
10
0
14
16
18
20
22
Q-6dB
R² = 0.4687
R² = 0.525
Fpeak (kHz)

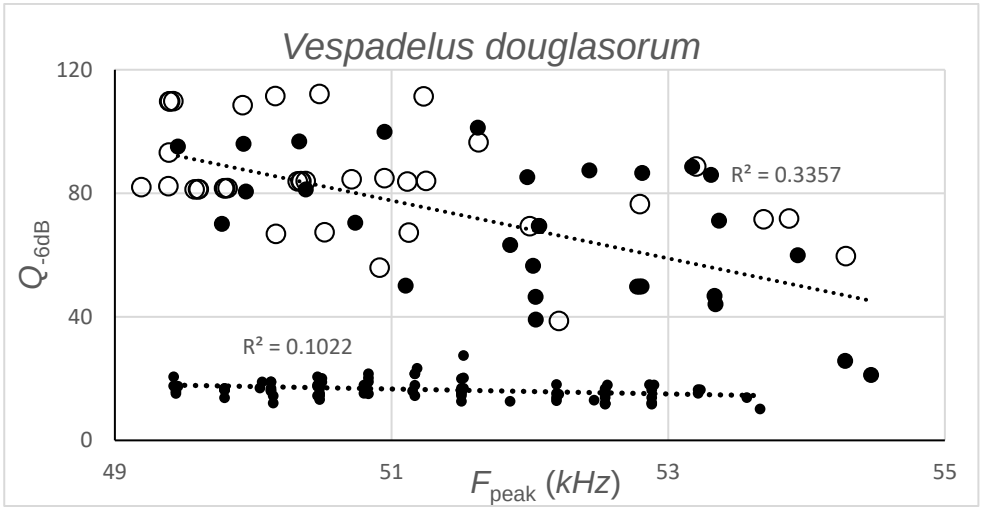

Scotorepens greyii
60
40
20
0
35
37
39
41
43
Q-6dB
R² = 0.4331
R² = 0.5924
Fpeak (kHz)

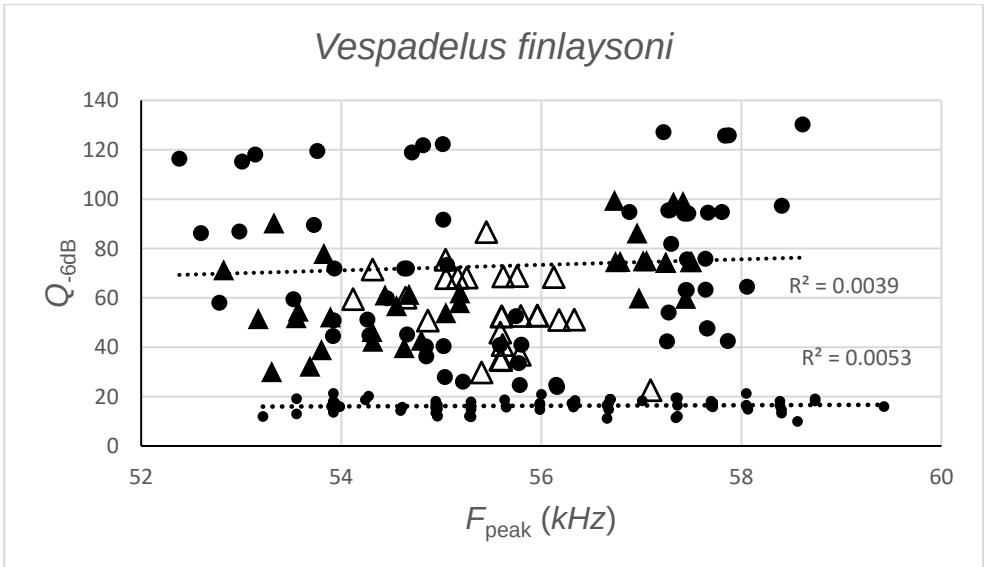

Scotorepens sanborni
80
60
40
20
0
Q-6dB
R² = 0.6546
R² = 0.5492
37
39
41
43
45
47
F peak (kHz)


Taphozous georgianus
80
60
40
20
0
Q-6dB
R² = 0.0031
R² = 0.0522
21
23
25
27
29
F peak (kHz)


Taphozous kapalgensis
80
60
40
20
0
Q SM
R² = 0.0207
23
24
25
26
F peak (kHz)


Vespadelus caurinus
140
120
100
80
60
40
20
0
56
58
60
62
64
66
Q-6dB
R² = 0.0195
R² = 0.0733
F peak (kHz)


Vespadelus douglasorum
120
80
40
0
49
51
53
55
Q-6dB
R² = 0.3357
R² = 0.1022
F peak (kHz)


Vespadelus finlaysoni
140
120
100
80
60
40
20
0
52
54
56
58
60
Q-6dB
R² = 0.0039
R² = 0.0053
F peak (kHz)

Appendix 3. Pulse peak frequency (F_{peak}, kHz) and full spectrum fineness-of-tuning (Q_{-6dB}) values derived from search-mode echolocation sequences recorded on the Northern Territory coast, near Pine Creek and in tropical Western Australia (average, *S.E.M.*, n). Reference as well as 'identified' sequence data are included.

n = number of pulse sequences. The F_{peak} averages exclude Nyctophilinae 'departure' calls (McKenzie and Bullen 2012), but the molossid averages include values for 'un-cambered wing' sequences (Bullen *et al.* 2013). Student t-test results (2-tailed, unequal variances): * *P*. < 0.05, ** *P*. < 0.01, *** P. < 0.001. Pop^n: data from WA's Kimberley (K) and Pilbara (P) populations are merged for some species.

	F_{peak} **NT**	F_{peak} **WA**	Q_{-6dB} **NT**	Q_{-6dB} **WA**	**Pop^n**
Aa	11.9 (0.1, 7)	12.5 (0.2, 59)**	21,4 (0.8, 7)	19.1 (0.6, 32)*	K, P
Cg	30.7 (0.3, 18)	31.5 (0.2, 46)*	32.6 (2.2, 18)	36.4 (2.0, 18)	K, P
Cj	17.6 (0.4, 11)	17.8 (0.2, 65)	25.9 (0.7, 11)	24.9 (0.8, 20)	K, P
Cn	40.1 (0.4, 30)	40.5 (0.4, 16)	57.0 (2.2, 30)	55,2 (3.6, 16)	K
Ma	42.9 (1.0, 13)	46.6 (0.6, 17)**	9.8 (1.2, 13)	9.4 (0.3, 17)	K
Ms	49.1 (0.3, 21)	48.8 (0.3, 13)	48.5 (3.5, 21)	54.4 (4.6, 13)	K
Na	53.1 (0.4, 29)	51.4 (0.5, 15)	8.0 (0.4, 29)	6.8 (0.5, 15)	K, P
Nd	58.8 (0.3, 12)	58.0 (0.8, 13)	6.1 (0.4, 12)	8.1 (0.5, 13)**	K, P
Ng	46.7 (0.3, 15)	47.2 (0.3, 13)	6.1 (0.3, 15)	6.7 (0.3, 13)	K
Nw	58.0 (1.1, 18)	57.0 (1.0, 14)	12.5 (1.5, 18)	12.0 (1.3, 14)	K
Oc	31.1 (0.5, 26)	31.5 (0.2, 76)	55.6 (1.9, 26)	52.1 (1.3, 32)	K, P
Ol	26.6 (1.3, 3)	27.2 (0.2, 52)	36.8 (4.4, 3)	33.3 (4.0, 12)	K, P
Pa	46.1 (0.3, 16)		55.8 (6.7, 16)		
Pw	48.0 (0.3, 28)	48.6 (0.3, 14)	94.4 (2.1, 28)	90.5 (1.7, 14)	K
Sc	20.7 (0.2, 16)	20.5 (0.2, 24)	37.8 (1.7, 16)	32.7 (1.1, 24)	K
Sf	17.8 (0.5, 15)	18.5 (0.3, 35)	30.1 (0.8, 15)	30.4 (0.7, 35)	K, P
Sg	38.5 (0.2, 31)	37.8 (0.5, 7)	29.7 (1.2, 31)	32.4 (3.0, 7)	K
Ss	40.8 (0.5, 22)	40.7 (0.5, 12)	29.1 (3.2, 22)	34.6 (3.5, 12)	K
Tg	27.0 (0.5, 13)	24.8 (0.2, 23)***	50.1 (2.3, 13)	49.6 (0.9, 12)	K
Tk	24.8 (0.2, 14)	24.9 (0.3, 9)	41.6 (2.0, 14)	44.5 (2.2, 9)	K
Vc	60.3 (0.3, 12)	60.9 (0.2, 48)*	66.3 (6.9, 12)	85.2 (3.8, 20)*	K
Vd		51.4 (0.4, 14)		74.2 (5.2, 14)	K
Vf	55.4 (0.3, 13)	56.0 (0.2, 45)	61.2 (4.6, 13)	73.1 (8.5, 12)	K, P

Appendix 4. Zoophagic bats comprising the communities of bioregions in tropical North-western Australia, presented according to their foraging strategies.

Foraging strategies are defined in 'Methods'. Bioregion codes: DAC, Darwin Coastal; ARC, Arnhem Coast; GUC, Gulf Coastal; NOK-L, Northern Kimberley landward; NOK-M, Northern Kimberley mangroves; VIB-L, Victoria Bonaparte landward; VIB-M, Victoria Bonaparte mangroves; CEK, Central Kimberley; DAL-L, Dampierland landward; DAL-M, Dampierland mangroves; OVP, Ord Victoria Plains; GSD, Great Sandy Desert; PIL-L, Pilbara landward; PIL-M, Pilbara mangroves; TAN, Tanami Desert; GAS, Gascoyne; CARN-L, Carnarvon Basin landward; CARN-M, Carnarvon Basin mangroves; LSD, Little Sandy Desert. *Th* (*Taphozous hilli* Kitchener) and *Sb* (*Scotorepens balstoni* (Thomas, 1906) are not included in Table 2.

Usual Foraging Strategy	**Bioregional Communities**																	
	DAC	**ARC**	**GUC**	**NOK-L**	**NOK-M**	**VIB-L**	**VIB-M**	**CEK**	**DAL-L**	**DAL-M**	**OVP**	**GSD**	**PIL-L**	**PIL-M**	**TAN**	**GAS**	**CARn-L**	**CARn-M**	**LSD**
Interceptor	*Cj Ol Aa*	*Cj Ol*	*Cj Ol*	*Cj Ol*	*Cj*	*Cj Ol Aa*	*Cj*	*Cj Ol*	*Cj Ol Aa*	*Cj*	*Cj Ol Aa*	*Cj Ol Aa*	*Cj Ol Aa*	*Cj Aa*	*Cj Ol Aa*	*Cj Ol Aa*	*Cj Ol Aa*	*Cj Aa*	*Cj Ol Aa*
Surface	*Ha Hs Hi Ng*	*Ha Hs Ng*	*Ha Hs Ng*	*Ha Hs Ng*	*Ha Hs Ng*	*Ha Hs Ng*	*Ha Ng*	*Ha Hs Ng*	*Ha Ng*	*Hs Ng*	*Ha Hs Ng*	*Ng*	*Ng*	*Ng*	*Ng*	*Ng*	*Ng*	*Ng*	*Ng*
Air Superiority	*Nd Na Ms Ra Cg Cn Vc Pa Sc Pw Sg Ss Sf Ma Tg Tk Nw Oc*	*Nd Na Ms Ra Cg Cn Vc/Vf Pa Sc Pw Sg Ss Sf Ma Tg Tk Nw Oc*	*Nd Na Ms Ra Cg Cn Vc/Vf Pa Sc Pw Sg Ss Sf Ma Tg Tk Nw Oc*	*Nd Na Ms Ra Cg Cn Vc Sc Vd Sg Sf Ma Tg Nw*	*Na Ms Ra Cn Vc Sc Pw Ss Sf Ma Tg Nw Oc*	*Nd Na Ms Ra Cg Cn Vc Sc Vd Sg Tg Tk Nw*	*Na Ms Ra Cg Cn Vc Sc Pw Ss Sf Tg Tk Nw Oc*	*Nd Na Ms Ra Cg Cn Vc Sc Vd Sg Tg Nw*	*Nd Na Ms Ra Cg Cn Vc/Vf Sc Vd Sg Tg*	*Na Cg Cn Sc Pw Ss Tg Oc*	*Nd Na Ms Cg Cn Vc/Vf Sc Vd Sg Sf Ma Tg Nw*	*Cg Vf Sg/Sb Sf Th*	*Nd Ra Cg Cm Vf Sg Sf Tg/Th*	*Na Cg[a] Vf Ss Tg Oc*	*Cg Vf Sg/Sb Sf Th*	*Nd Ra Cg Cg Vf Sg/Sb Sf Tg/Th*	*Cg Vf Sg Th/Tg*	*Na Cg[a] Vf Sf Tg Oc*	*Ra Cg Vf Sg/Sb Sf Tg/Th*
Variables																			
# S & A taxa [b]	22	21	21	17	16	18	16	17	15	12	16	6	9	8	6	8	6	7	7
Total # taxa [b]	25	23	23	19	17	21	17	19	18	13	19	9	12	10	9	11	9	9	10
Average annual rainfall in wettest isohyet (mm)	1730	2000	900	1400	1350	1000	1000	950	800	800	750	400	425	325	375	300	300	300	250

Cavernous ranges [c]	2	3	1	3	3	3	3	3	3	0	3	1	3	1	1	3	2	1	2
Riparian systems [c]	3	3	3	3	2	3	1	3	3	1	3	1	3	2	1	2	2	1	1
mangrove forest [c]	3	3	3	0	3	0	3	0	0	2	0	0	0	2	0	0	0	2	0
Mangal area (km^2)	316	585	149	0	929	0	231	0	0	274	0	0	0	173	0	0	0	64	0
Average *AR*	6.75	6.69	6.69	6.70	6.70	6.82	6.81	6.70	6.86	6.89	6.80	6.92	6.95	7.00	7.15	7.03	7.10	7.17	7.17
lower *SE*	6.67	6.60	6.60	6.60	6.59	6.71	6.70	6.60	6.74	6.76	6.69	6.77	6.81	6.85	6.99	6.88	6.95	7.00	7.03
upper *SE*	6.84	6.78	6.78	6.81	6.82	6.92	6.93	6.81	6.97	7.03	6.91	7.07	7.09	7.15	7.31	7.17	7.25	7.33	7.31
Average F_{peak} (kHz)	46.75	47.63	47.63	49.61	50.42	46.65	45.99	49.61	45.08	39.03	44.77	39.99	33.19	39.08	30.24	32.34	37.21	30.34	30.34
lower *SE*	44.11	44.94	44.94	46.54	47.06	43.69	42.70	46.54	41.96	36.47	41.96	36.17	31.08	35.12	27.85	30.14	33.17	27.96	28.28
upper *SE*	49.38	50.32	50.32	52.68	53.77	49.61	49.27	52.68	48.20	41.59	47.57	43.81	35.30	43.04	32.64	34.55	41.25	32.73	32.41
Average m_{bat} (kg)	0.0136	0.0121	0.0121	0.0123	0.0121	0.0141	0.0134	0.0123	0.0143	0.0142	0.0137	0.0160	0.0166	0.0164	0.0183	0.0177	0.0171	0.0179	0.0179
lower *SE*	0.0125	0.0110	0.0110	0.0110	0.0107	0.0128	0.0120	0.0110	0.0130	0.0124	0.0124	0.0140	0.0147	0.0145	0.0161	0.0158	0.0151	0.0157	0.0160
upper *SE*	0.0148	0.0132	0.0132	0.0135	0.0135	0.0154	0.0149	0.0135	0.0157	0.0159	0.0150	0.0179	0.0185	0.0183	0.0206	0.0196	0.0191	0.0201	0.0198

[a] included although known from landward edge of mangroves only.

[b] closely related allopatric con-generics occupying the same foraging niche were treated as a single taxa (e.g. *Vc/Vf*)

[c] 3, extensive or numerous in wettest part of bioregion; 2, only a few small areas in wettest part; 1, a few small but not in the wettest part; 0, none at all.

[d] *M. gigas* is excluded from this analysis (see Methods).